EARLY WARNING SYSTEMS FOR DISASTER RISK REDUCTION IN INFORMAL SETTLEMENTS: DURBAN'S CBFEWS

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1. INTRODUCTION & OVERVIEW

Informal settlements are disproportionately exposed to the impacts of escalating flood risk due to the interaction between climate change events and high levels of vulnerability. This has led to devastating loss of lives, land, homes, and livelihoods globally. As climate risks intensify and increasingly intersect with development and planning challenges, there is an urgent need to establish effective early warning systems for floods and extreme weather events. Despite the growing number of early warning systems globally, accelerated by the 'Early Warnings for All' initiative, critical gaps persist in understanding and documenting their development, implementation, and long-term sustainability, and in determining at what scale they should be implemented. These include gaps in governance and coordination, integration of local and indigenous knowledge, inclusivity and accessibility for vulnerable populations, technical interoperability, knowledge integration, capacity building for both developers and users, and mechanisms for community ownership and maintenance. It is evident that the localisation of these warning systems is critical.

In resource constrained situations there is also a need for these systems to be low technology, low cost and accessible to all households. A key challenge is to determine at what local scale early warning systems are most effective, while still being able to scale them across local regions through horizontal and vertical pathways.

Community-based flood early warning systems (CBFEWS) can provide locally-specific[1] and timeous information when state agencies and research institutions co-produce knowledge with communities on levels of flood risk and flood response strategies. This briefing document analyses a CBFEWS that has been effectively demonstrated in the Quarry Road West informal settlement in the Palmiet River catchment in Durban, South Africa[2].

This initiative emerged as a response to an urgent need identified by informal settlement residents through their engagement with the state, formal residents and university actors, within a catchment rehabilitation project, of which they were also a part.

Durban's CBFEWS offers critical insights as part of the global-to-local early warning and adaptation ecosystem and proof of concept for locally-led, people-centred early warning systems in African cities.

It is important to define what is meant by a local scale. Local refers to a small and specific geographic area, defined by a range of characteristics, which can include being a neighbourhood, a community, a sub-catchment or even a city. It is used to define an area that has particular patterns, relationships, activities and interactions and is bounded by the 'size of the lens' used to define it, by those working in a local space or through it.

This briefing consolidates existing knowledge and learning on the Palmiet Catchment Rehabilitation Projects' (PCRP)[3] CBFEWS and highlights current work underway to strengthen and expand this work[4].

Over a period of ten years, the CBFEWS has continued to evolve, integrating scientific, technical, local and indigenous knowledge on rainfall data and flood risk information in the Palmiet catchment.

[1] Local refers to a small and specific geographic area, defined by a range of characteristics.
[2] O'Donoghue et al., (2025)
[3] Sutherland (2025)
[4] O'Donoghue et al., (2025)

Thousands lost their homes during the Durban floods.

This includes using scientific weather warnings from the South African Weather Service and eThekwini Municipality's[5] Forecast Early Warning System (FEWS). The CBFEWS also includes proactive actions related to disaster preparedness, capacity building and response in vulnerable communities.

The CBFEWS has developed organically from the bottom up, and has adapted over time, which has led to ongoing lessons and iterative learning, relevant to applying CBFEWS in other contexts. This is not to say that the same process should be followed in other contexts. There are universal processes that have emerged from the PCRP CBFEWS that can be applied more generally and across the city and elsewhere. However, context matters and each system must evolve taking the particularities of place and context, and relationships amongst specific actors in each locale, into account.

Why we need early warning systems at a local scale

In many cities, state capacity to forecast and issue local-scale early warnings is limited, making CBFEWS critical for complementing larger scale warning systems. Communities are often the first responders after disasters, and their pre-event knowledge and experience strengthens post-event action. Localised warnings also take local conditions into account and so ensure that the translation of risk to the local scale is more accurate and timeous. Localisation of early warnings is critical but challenging. For example, in South Africa, only the South African Weather Service (SAWS) can legally issue official severe weather warnings, which are typically at municipal scale.

These broad alerts often fail to reflect local level variations, or are not well understood by local communities, creating "warning fatigue" when expected conditions do not materialise locally and misunderstanding of actual risk. Communities sometimes ignore warnings due to past false alarms or unclear messaging, underscoring the need for highly localised warnings, even at sub-catchment level. Localised systems can improve spatial and temporal accuracy, provide clearer timings of rainfall peaks and declines, and reflect catchment-specific response times, as the Palmiet Catchment's CBFEWS has shown. This enhances trust and ensures communities act on warnings relevant to their area. Early warning systems are vital, but their effectiveness is largely shaped by the degree of integration with local knowledge to improve accuracy and community relevance, as well as ongoing community engagement and training to support understanding and trust in localised messaging.

[5] eThekwini Municipality is the local authority responsible for the administration of the eThekwini Municipal Area (EMA). Durban and eThekwini are both used as names for the EMA, which is a metropolitan city.

Community members clean up and repair post flooding events.

2. EVOLUTION OF THE CBFEWS IN THE PALMIET CATCHMENT, DURBAN

Climate change and flood events in Durban, South Africa

In April 2022, extreme rainfall in KwaZulu-Natal, caused floods that killed over 450 people, displaced 40 000, damaged or destroyed 13 500 homes, affected 630 schools, and caused infrastructure losses exceeding R80 billion[6]. Roads, bridges, pipelines, and treatment plants were badly hit, disrupting key economic sectors. Durban was particularly hard hit and has faced multiple major floods since 2016, with climate change projected to intensify storms and flooding, compounded by urban development, poor urban planning, environmental degradation, and social vulnerability[7]. Early Warning Systems are critical tools to reduce loss of life and livelihoods. However, there is also growing recognition of the need to ground scientific and technical warnings with more nuanced local knowledge that helps refine the accuracy of these warnings, and to understand how the location and scale of the associated risks and impacts are understood by communities.

The impacts of climate variability and change are unequal, shaped by race, gender, class, geography, and political agency. Informal settlements bear the brunt due to high exposure, vulnerability, and marginalisation. In these areas, community-based early warning systems are especially critical to reducing risk and protecting lives.

An emerging 'Community of Innovators' in the Palmiet Catchment Rehabilitation Project (PCRP)

The CBFEWS emerged through the PCRP, a demonstration project under the uMngeni Ecological Infrastructure Partnership, which promoted ecological infrastructure for supporting water quality and supply. Stakeholder dialogues led to rehabilitation actions and the formation of a Community of Innovators (CoI), which is an informal, flexible coalition of academics, community leaders from formal and informal settlements (notably from Quarry Road West), municipal officials, and civil society in the Palmiet Catchment in 2014[8].

The participatory governance platform that was consequently established enabled experimentation and localised interventions, such as training community members to conduct risk assessments in the settlement and identify climate adaptations[9]. Initially, flood risk was not a core focus of the PCRP, as a result of the 2015 to 2017 drought, but from 2016 increasing floods and concerns expressed by community members and the PCRP shifted attention. University researchers and municipal officials realised that rainfall gauges in the upper catchment, which measured rainfall data, and river flow visuals collected by local residents, could be connected to flood risk experienced by the informal settlement in the lower catchment.

A Technical WhatsApp group was created on 23 February 2016 for the PCRP to share information on flood related catchment risks. Quarry Road West residents did not have access to smartphones at this point, relying on UKZN researchers to relay updates telephonically. Legal requirements also shaped the development of the CBFEWS: warnings from the South African Weather Service (SAWS) precede all other alerts. The CoI adapted by aligning with SAWS protocols and tailoring warnings locally. Through experiential learning between members of the CoI, thresholds were refined—for example, it was learnt that over 45mm of rain over 3 - 5 hours in the Upper Catchment, led to the Palmiet River flooding in Quarry Road West. Communities distinguished between pluvial flooding (surface and stormwater inundation) and fluvial flooding (river overflow and bank collapse). UKZN researchers and climate adaptation municipal officials played a key role in mediating information flows, translating local knowledge provided by communities into the Technical WhatsApp group to improve accuracy and responsiveness.

[6] Pinto et al. (2022); DRRS, 2024
[7] EThekwini Municipality (2024)
[8] Sutherland (2025)
[9] Mazeka et al., 2019; Sutherland et al., 2019; Sutherland, 2025

Smartphones and data as key enablers for the effective functioning of the CBFEWS

In 2017 a breakthrough occurred when due to lower costs, informal settlement residents gained access to smartphones and data, and connected to WhatsApp messaging. A community-based WhatsApp group called 'the Quarry Road Team' was established, which included university researchers and informal settlement residents. Warnings from SAWS and risks identified higher up in the catchment, which were communicated on the Technical WhatsApp group, were sent to the community-based WhatsApp group by university researchers. Community members posted images of the river back to the community-based WhatsApp group, thereby creating bi-directional learning. This information was shared with the Technical WhatsApp group, where municipal officials and university researchers interpreted the information and were able to share improved warnings on both groups, based on previous experience.

Integrating the community-based and municipal early warning systems

During this period, eThekwini Municipality continued to develop its Forecast Early Warning System (FEWS), an open-source platform using global rainfall forecasts, SAWS forecast rainfall, radar, observed rainfall, and stream telemetry to identify areas most at risk. FEWS reports are central to the City's Joint Operations Centre meetings for disaster risk reduction following SAWS alerts above Level 4, with CBFEWS now a standing agenda item.

In 2018, the Senior Manager of the Coastal Stormwater and Catchment Management Department (eThekwini Municipality) began to collaborate with the PCRP through the then Municipality's Climate Protection Branch (now the Climate Change Adaptation Branch) and the UKZN researchers (both leading stakeholders in the PCRP), using the Municipality's FEWS. The FEWS included data from a municipal owned radar located at UKZN, and more recently, due to the failure of this municipal radar, the SAWS radar in the located north of Durban. These radars provide data on storm events in the Palmiet Catchment. After discussions in November 2019 between members of the PCRP and the Senior Manager of the Coastal Stormwater and Catchment Management Department, integration between the systems advanced when the FEWS official joined the Technical WhatsApp group, sharing real-time radar, rainfall, and river data for the Palmiet Catchment.

This greatly improved accuracy, reduced false alarms, and provided data that could be translated by climate adaptation officials and university researchers to warn and reassure residents during storms. The success relied heavily on the officials' and university researcher's expertise in interpreting data and tailoring it for community use. The university researchers were on the community WhatsApp group, with the lead researcher responsible for relaying weather warnings. However, dependence on one individual poses risks and this was corrected in 2025 when a municipal official joined the community WhatsApp group. It was important to build redundancy into the system, and ultimately, some automation, so that messages can go out to communities as soon as there is a risk of flooding, particularly during the night time. While other officials gained access to rainfall and stream data, radar access remained limited. Building redundancy in a system is essential and this was evident in the PCRP CBFEWS when the senior official responsible for FEWS retired, with members of the FEWS team successfully replacing him on the CBFEWS network, gaining experience very quickly in how the system worked. This highlights the importance of avoiding reliance on individual champions and considering safeguards, such as training up others to assume similar responsibilities and possibly using automation and AI. However the CBFEWS has shown that human-centred contextual knowledge, experience and intuition are central when dealing with localised early warnings.

The process described above led to the development of a CBFEWS that plays a continued significant role in reducing flood risk in Quarry Road West informal settlement[10]. During the April 2022 KwaZulu-Natal floods, the Palmiet Catchment's CBFEWS is estimated to have saved the lives of between 250 and 400 people in the Quarry Road West informal settlement[11]. Early SAWS alerts, integrated with the City's FEWS and local WhatsApp networks, ensured residents were warned, mobilised, and evacuated before floodwaters destroyed land and homes. Despite challenges such as load-shedding and blocked bridges, the CBFEWS partnership prevented widespread loss of life and demonstrated the critical value of combining municipal forecasts with local knowledge, joint communication channels and community action.

Since 2022, CBFEWS has been repeatedly activated and strengthened through iterative learning, new monitoring gauges, and expanded redundancy to function even when parts of the system fail. The INACCT Resilience Project is now documenting these lessons, highlighting how integrating technical expertise with local knowledge underpins success[12]. This work is informing efforts to scale CBFEWS to other vulnerable communities, offering a practical, people-centred model for disaster risk reduction and climate resilience.

3. HOW THE CBFEWS WORKS

In short, the system relies on scientific and technical information (e.g. from SAWS, the municipal FEWS, municipal rain and stream gauges, and radar) and real-time community data, and the translation and integration of these different types of data, to communicate more accurate flood warnings and updates via WhatsApp groups to those in the catchment, particularly the most vulnerable.

Scientific and Technical FEWS

The Coastal Stormwater and Catchment Management Department in eThekwini Municipality maintains and operates the FEWS which links hydraulic models (PCSWMM[13]), weather forecast data, rainfall data, coastal models and warning systems to generate more accurate indications of where flooding will take place within the eThekwini Municipal Area (Figure 1), thereby reducing infrastructure damage and loss of life[14]. More specifically, the hydraulic models of the FEWS make use of a global numerical weather prediction system (the 'Global Forecast System') and fine scale forecast rainfall data from SAWS to run forecasted flood simulations for the municipal area.

Locally-collected real time data on rainfall and stream levels and real-time radar information also helps provide real-time information on storm cells and their paths, thus helping to improve the localisation of rainfall patterns which in turn improve the warning information to those on the ground in the catchments. The system can predict the effects of disasters like flooding ahead of time, allowing more time for emergency response systems to be implemented[15]. The FEWS is the first of its kind in South Africa and Africa[16].

A site visit to Umzinyathi Peri-Urban Settlement (eThekwini) forms part of efforts to pilot the upscaling of the CBFEWS.

[10] Sutherland (2025)
[11] Sutherland (2024)
[12] The 'Designing Inclusive African Coastal City Resilience' (INACCT Resilience) project is an action-oriented research project that aims to strengthen proactive, inclusive and evidence informed gender responsive urban resilience planning in African coastal cities. The specific focus is on informal settlements in the project's two case study cities: Durban (South Africa) and Beira (Mozambique). Both cities have recently experienced extreme flooding that caused severe urban and environmental damage, displacement and loss of life.
[13] PCSWMM – 'Personal Computer Storm Water Management Model' – PCSWMM is advanced modelling software for stormwater, wastewater, watershed and water distribution systems.
[14] Tooley (2025, in draft)
[15]https://www.durban.gov.za/storage/Documents/Sustainable%20Development%20Goals/FEWS.pdf
[16]https://www.durban.gov.za/storage/Documents/Sustainable%20Development%20Goals/FEWS.pdf

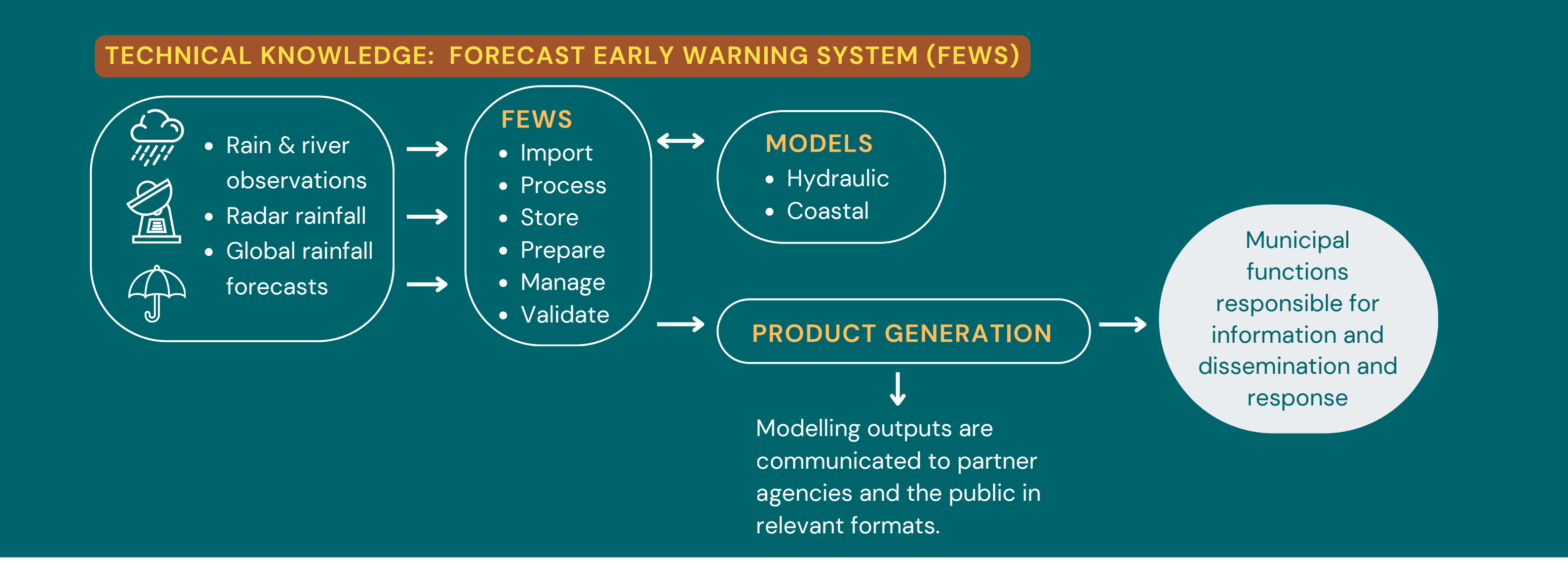

Figure 1: An overview of eThekwini Municipality's FEWS, the data it draws from and how this is processed to generate data displays and products that can be shared with other municipal departments, partner agencies and members of the public (Source: Geoff Tooley, former employee in eThekwini Municipality's Coastal Stormwater and Catchment Management Department).

Integrating scientific, technical and community knowledge into the CBFEWS

There is growing recognition of the need to ground technical warnings with more nuanced local knowledge that helps refine the accuracy of these warnings, and the location and scale/level of the likely risks and impacts so that communities can respond more effectively. This requires the integration of scientific and technical knowledge outputs, such as the FEWS warnings, with real-time community data (civic science) in specific high-risk locations.

As indicated earlier in this briefing, this integration of scientific, technical and community knowledge is central to Durban's Palmiet River catchment's CBFEWS (Figure 2).

In the early days of the CBFEWS, the knowledge produced by the PCRP partners on rainfall levels, river levels and flood risk during storm events was integrated by climate adaptation municipal officials and university researchers from UKZN[17] and used to help inform flood risk warnings in the area. As noted, by 2017, once smartphones and mobile data became more accessible, informal settlement residents were included in a community-based WhatsApp group, which was connected to the Technical WhatsApp group by university researchers. This further enhanced the effectiveness of the localised warning system. With over a decade working together, and with the city having experienced a number of floods since the CBFEWS was established, there have been important observations and learnings around what local knowledge, data and networks are most critical in helping to inform and strengthen flood early warning systems. These have included:

Time-stamped observations of changing river levels in specific community locations

- Community observations of changing river levels over time are important in helping to develop correlations between upstream river and rainfall levels and when these are likely to translate into downstream impacts. These observations can be shared through WhatsApp messages and time-stamped photos and videos to generate live community-based data on the rate at which river levels are rising over time.

Local thresholds related to river levels and impacts

- The Quarry Road West informal settlement residents, working with researchers and city officials, are beginning to understand critical 'threshold points' at which specific impacts start to be experienced. For example, when the water level at the upstream Birdhurst stream gauge is over 1.7m, the river downstream at Quarry Road West starts to break over river-banks and scour them, undermining homes and other structures. If the river rises above this level, warnings are given through the WhatsApp group. Once the river level drops below 1.7m at Birdhurst and continues dropping, it is safe for the community to go back to their homes within 1-2 hours.[18]

Time lags between stream gauge readings and downstream impacts

- Understanding time-lags helps communities know how much time they have to respond or vacate depending on their location and catchment gradients relative to the gauges[19]. For example, observations over time have shown that there is an estimated 40-minute lag time between the stream gauge readings at Birdhurst upstream of Quarry Road West and when these levels reach the settlement.

Local understanding of areas of risk and vulnerability

- Local understanding of areas of high risk and vulnerability is important in focusing response and evacuation efforts. For example, understanding where highly erodible soil is located, and how flow velocity and direction changes in the river, can help predict where impacts will be most acutely experienced[20].

[17] School of Built Environment and Development Studies
[18] Technical CBFEWS meeting notes, UKZN, 23/04/2025
[19] Technical CBFEWS meeting notes, UKZN, 23/04/2025
[20] Institute of Natural Resources (2023)

The integration of scientific, technical and community knowledge has helped strengthen the CBFEWS and reduce the loss of life. It has also strengthened relationships between informal settlement residents, researchers and local government officials, which has helped facilitate other opportunities, including engagement in river rehabilitation projects and learning exchanges with other informal settlements. Very localised warnings contribute towards building trust in the messaging and eliciting an appropriate response amongst recipients. By drawing on local and indigenous knowledge, as in the case of Quarry Road West, the warnings can be fine-tuned and ground truthed which increases community buy-in to the process, strengthens capacity and improves the efficacy of warnings.

Balancing the formal requirements of municipal systems with the agility of informal community networks is critical but presents significant challenges for early warning systems. Municipal processes are shaped by formal protocols, communication hierarchies, and liability considerations, which can slow the flow of information. By contrast, informal systems such as community WhatsApp groups rely on speed, trust, and flexible structures to mobilise immediate action. Balancing municipal priorities of accuracy and accountability, with timeliness, accuracy and collective response priorities of local communities is critical. A key tension lies in ensuring that critical data and alerts move quickly enough to be useful, without undermining the credibility or authority of official channels. Achieving this balance is necessary, as effective early warning systems depend on combining the institutional legitimacy, resources and knowledge systems of formal systems with the institutional legitimacy (through alternate norms and codes), dynamism, responsiveness and embedded knowledge of informal community-led networks.

Communicating early warnings across the eThekwini Municipal Area

Despite improvements to the CBFEWS in Quarry Road West, broader dissemination of early warning information remains a challenge across the eThekwini Municipal Area, not because warnings are not disseminated by the Communications Unit in the municipality, but rather because of the way in which these warnings are received and understood. Once a flooding threat is identified, communication begins between SAWS, the Municipality's FEWS Team, and Disaster Management through the Joint Operations Centre and municipal social media platforms. Information is relayed to other officials, emergency services, and the public, with messaging tailored to each group: Disaster Management needs precise location, timing, and severity details, while communities need clear guidance on expected impacts and actions. With more than 250 high-risk flood zones identified across the city, prioritising clear communication to these communities is critical.

Effective warnings depend on using local structures and communication channels, supported by community leadership. In Quarry Road West, heavy rainfall advisories for the Palmiet catchment are posted on the community-based WhatsApp group, linked to a technical group of municipal officials and researchers (Technical WhatsApp group). This interface enables translation of scientific and technical forecasts into accessible messages and incorporates real-time community feedback, photos and river updates, that improve situational awareness. Redundancy in communicators ensures continuity, while aligned messaging across groups - developed through experience over many years - helps warnings reach residents quickly and consistently. In this way, the warnings issued by SAWS are extended through more detailed and localised weather warnings generated through the relations, knowledge, technologies and communication mechanisms of the actors involved in the CBFEWS.

Community members use creative arts to envisage effective early warning systems and evacuation plans.

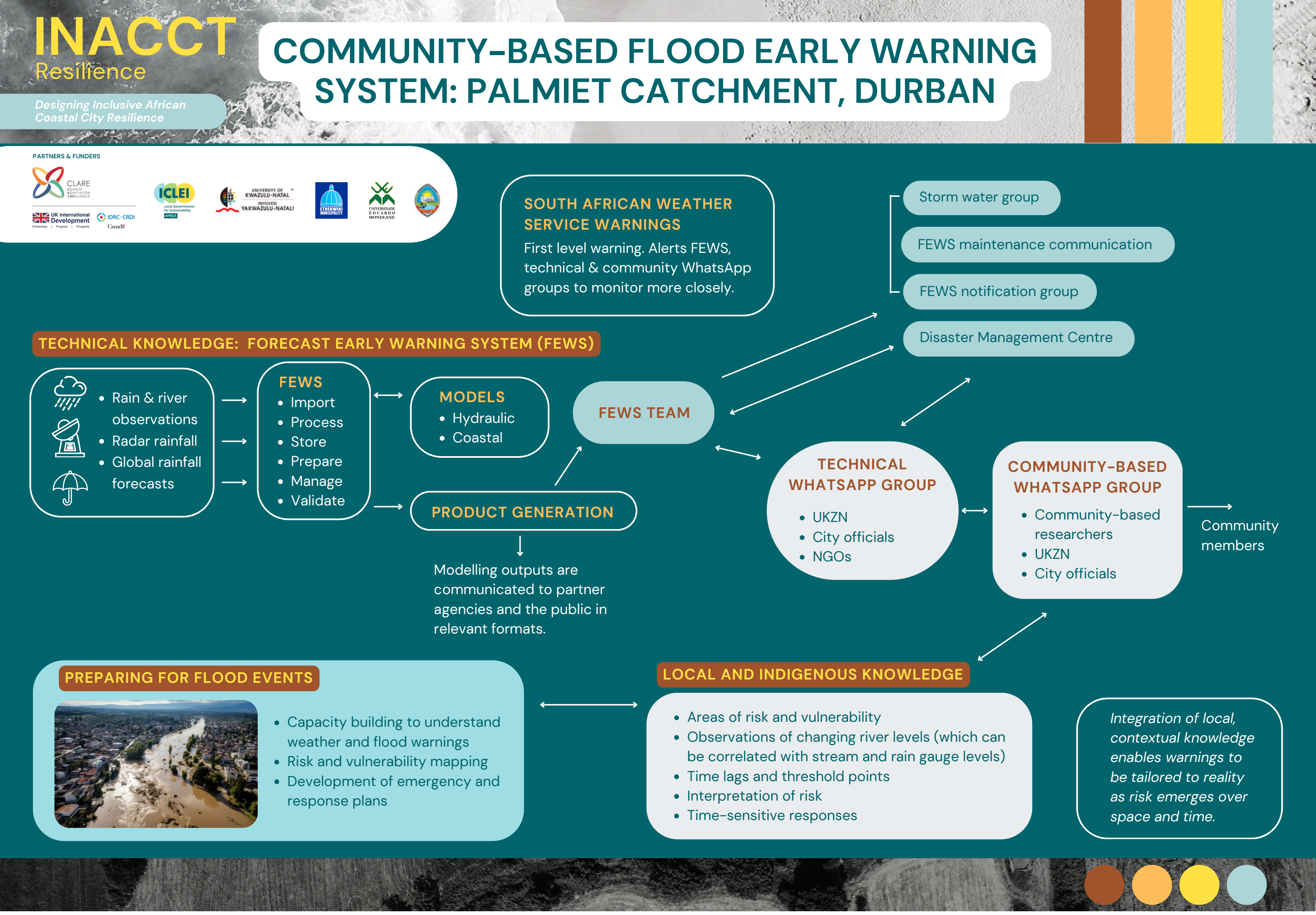

Figure 2: A simplified representation of the Durban CBFEWS, showing the communication channels that exist to communicate warnings to municipal functions and to the Palmiet WhatsApp groups. These communication channels facilitate the integration of local knowledge into the technical data produced, so that flood warnings can be refined.

4. FLOOD WARNING PREPARDNESS & RESPONSE

The CBFEWS and the flood warnings that it generates are just one part of a broader process that is required to prepare communities to respond appropriately to flood warnings so that impacts are reduced. This process should include pre-flood risk mapping and response planning at community level, building capacity and trust to understand and act appropriately on the warnings received, and equipping communities with the physical materials that they need to raise the alarm and mobilise the broader community.

Risk mapping and response planning

In Quarry Road West, researchers from the University of KwaZulu-Natal's School of Built Environment and Development Studies have been working over time with community members to generate risk maps that help deepen and expand an understanding of the spatial distribution of various risks (including flood risk) [21]. Maps sketched by the community highlight geo-referenced risk areas and also include household level information that can inform disaster response[22].

Once risks and vulnerabilities are understood in relation to specific disaster events, response plans can help direct appropriate action when an event takes place. These should include clear evacuation maps to indicate safe routes to follow, and locations where community members should gather in the event of a disaster[23]. They should also include proactive interventions, such as clearing litter and plant debris from pipes and drains to reduce the impacts of flooding[24].

These response plans should be developed collaboratively between municipal officials, researchers and the community, given the need to combine different knowledges for best practice responses, including the community's nuanced understanding of dynamics at that level, and to ensure that there is ownership of the responses that have been agreed to. Regular communication of these response plans and 'trial runs' are also critical in ensuring that everyone is prepared when a disaster event takes place[25].

[21] Institute of Natural Resources (2023)
[22] Mazeka et al (2019); Sutherland et al (2019)
[23] Technical CBFEWS meeting notes, UKZN, 23/04/2025; Focus group with residents from Quarry Road West and Pholani informal settlements, held at UKZN, 16/08/2024
[24] Focus group held with residents from Quarry Road West informal settlement focused on early warning and emergency toolkits, held at UKZN, 10/04/2025
[25] Technical CBFEWS meeting notes, UKZN, 23/04/2025

Building capacity and trust to understand warnings

Community response to flood warnings depends on both understanding and trusting the messages issued. Education, capacity building and training are therefore essential to strengthen uptake and response. This includes clearly articulating levels of risk and corresponding actions, for example, staying alert under low-risk conditions, versus evacuating to safe locations under severe risk. Capacity building also requires integrating local, indigenous, scientific and technical knowledge to build trust and relevance. In Durban, for example, beliefs such as the Inkanyamba (the snake that moves through water or the sky causing disasters) or practices like banging pots and pans to ward off floods, which serves as an effective, audible warning, can be linked to scientific and technical knowledge systems.

Gender and inclusion are central to ensuring that early warning systems protect all residents effectively. Women often act as first responders and information relays within households, while youth and persons with disabilities may face barriers to accessing warnings or evacuating safely. The CBFEWS has benefited from the active participation of women researchers and community leaders, whose involvement has deepened trust and social cohesion. Embedding gender-sensitive design and leadership opportunities in all stages, from training to risk communication, will ensure that CBFEWS remain inclusive and equitable.

[26] Focus group held with residents from Quarry Road West informal settlement focused on early warning and emergency toolkits, held at UKZN, 10/04/2025
[27] Focus group with residents from Quarry Road West and Pholani informal settlements, held at UKZN, 16/08/2024

Equipping communities to respond

As noted, in many instances, community members become 'first responders' in disaster situations and therefore should be equipped to undertake basic response tasks[26] . During a workshop with the Quarry Road West informal settlement community in April 2025, for example, residents prioritised critical equipment for different stages of a disaster and emphasised the importance of framing responses according to the level of risk being experienced.

Before a disaster event, visual cues, such as a brightly coloured flag, are needed to alert residents to the potential for an event and to remind them to stay alert and aware of other warnings that may come. Other visual signs, such as painted markings on local bridges to indicate river levels and associated risk, could also be helpful[27]. During a disaster event, equipment such as whistles, high visibility jackets, strong torches, gumboots and danger tape (to keep people away from rising river levels) are needed, along with a lifebuoy/rope, siren and first aid kit should the situation become more serious. Residents also highlighted the importance of signage to indicate evacuation routes and places of safety. In instances where warnings (like flag colours, whistles/sirens) need to be interpreted by community members, this needs to be communicated in advance of a disaster event.

Importantly, these toolkit items need to be developed per context. In one settlement for example, concern was expressed about using whistles as a warning, given that many children play with whistles and this could be misconstrued as a disaster warning or ignored during a serious event.

Capacity building sessions offer young community members and researchers a space to share experiences and insight.

5. UPSCALING THE CBFEWS

Technical inputs

Building on the scientific and technical knowledge and data that is already part of the FEWS, there are potential opportunities to automate the distribution of components of this information. For example, the team involved in the PCRP CBFEWS have indicated that it could be helpful to set up a certain level of automation of observation radar information updates for CBFEWS coordinators. This requires additional conversations regarding what resolution of information is possible and how frequently these could be updated[28].

Looking forward, the next evolution of Durban's CBFEWS could incorporate emerging digital tools to enhance accuracy and timeliness while maintaining community control. Artificial intelligence and machine learning could help automate pattern recognition in rainfall–streamflow data, while open-source cloud platforms can ensure data accessibility and transparency. However, these technologies should augment, not replace, local knowledge, experience and decision-making. Durban's experience illustrates the value of "augmented intelligence," where digital systems amplify human insight rather than override it.

In addition, INACCT funding has been used to appoint a service provider 'Obscape' who has tested correlations between rain gauge and stream gauge measurements. This research provides a cheaper and simpler method to provide data to inform early warnings in areas where more complex hydrological modelling is not possible. There are opportunities to build on these outcomes and further develop correlations between such measurements and how they translate into specific local contexts (e.g. in terms of actual river level and flowpaths) in additional pilot settlements for the CBFEWS. In these additional settlements, this will involve delineating the relevant catchment, characterising the flood-causing rainfall and determining the most appropriate locations for the rainfall and streamflow gauges. This data, along with historical and other records, provides the basis for training the model and testing its accuracy in these new locations.

[28] Technical CBFEWS meeting notes, 23/04/2025 – suggestion of 20 minute updates.
[29] Technical CBFEWS meeting notes, 23/04/2025

Community-based inputs

Although there are some aspects of the CBFEWS that could potentially be automated, there are other forms of human generated and locally-based knowledge that will always need to be integrated with any automated outputs, so that these are accurately translated into specific contexts. Local inputs that are emerging as being most important in adding to, refining and validating the scientific and technical outputs include CFEWS team members' (municipal officials, researchers, NGOs and communities) information on:

- Areas of highest vulnerability during flooding, and the individuals and groups that are most affected.
- River paths and river levels and how these change during a flood across the catchment. Time-stamped photographs and videos that provide an indication of river level can help to develop correlations with upstream rainfall and streamflow gauges to generate more nuanced understanding of the likely time-lags and the extent of flood-related impacts[29].

Local knowledge is also critical when exploring response plans and evacuation routes. The analysis and interpretation of the data currently cannot be automated as it is based on interpretation and experience, with nuanced understandings of the local context allowing the WhatsApp groups to determine levels of risk.

Local knowledge is the cornerstone to developing context-specific early warning systems.

Other enabling factors

In addition to being able to develop and expand scientific, technical and community knowledge for CBFEWS to be upscaled into additional settlements, there are a number of other enabling factors that have underpinned the success of the PCRP CBFEWS and which are likely to be important in other spaces. These include:

Relationships of trust:
Community members need to trust whoever is communicating flood warnings and the content of the warning itself. In the Palmiet Catchment, relationships and partnerships between the residents of Quarry Road West informal settlement, researchers and municipal officials were built up over many years, initially in the context of the PCRP[30]. In Quarry Road, the community learned to trust the system and each other, after seeing its positive impacts in reducing loss of land, houses, material possessions and life[31].

Intermediaries:
Intermediaries can help build relationships between the multiple actors that need to be involved in a successful CBFEWS. They can also help make connections across different elements of the system, for example linking scientific and technical information from weather warnings and radar data with local knowledge and helping to communicate this in a way that is easily understood. University researchers and progressive municipal officials are best placed to play this intermediary role as the PCRP CBFEWS has shown.

Institutionalisation and ownership

Sustaining the CBFEWS requires embedding it in formal governance frameworks. eThekwini Municipality's inclusion of the system as a standing item in Joint Operations Centre meetings is a step toward institutionalisation, but long-term sustainability also depends on dedicated budgets, technical capacity and continuity mechanisms within the City's Disaster Management and Climate Adaptation branches.

Establishing formal protocols for data stewardship, staff transitions and community liaison roles will safeguard institutional memory and ensure consistent functionality even when key individuals move on.

There is also a need to explore how CBFEWS models can be integrated into broader city or district-level by-laws and investment pipelines. This offers a pathway to scaling community-based early warning approaches through national-local partnerships.

[30] Sutherland (2025)
[31] Engel, K. (2025)

At learning labs, community members and key municipality officials have the opportunity to share knowledge and co-produce solutions.

6. KEY LESSONS LEARNED

Learnings from the existing CBFEWS experience include:

Expertise and support: For scientific and technical CBFEWS inputs, there is a need for appropriate expertise and support to manage and maintain the system and the data inputs[32].

The importance of context: The biophysical and socio-economic context of settlements can affect whether risk is evenly distributed or concentrated in specific areas. This has implications for how settlements prepare for and respond to flood events[33]. Context also affects the correlations between river heights, levels of impact and critical threshold points during flood events.

Geographic literacy: Developing geographic literacy (on for example weather, river, geological and settlement systems) across all actors in a CBEWS is essential to ensure understanding, and the integration of knowledge on social, environmental, economic, political and spatial systems within each context.

Experiential knowledge and integrating scientific, technical, local and indigenous knowledge: The translation of scientific and technical information into specific contexts relies on community knowledge of the local context. The two forms of knowledge therefore need to be integrated in relevant ways. It is also important to engage with indigenous knowledge systems and explore links with scientific and technical knowledge that could assist in strengthening capacity and awareness.

Communicating warnings[34]:

- Identify key people (community champions/'foot soldiers') in the community, who are committed to the process and who remain in place, to pass warnings to the rest of the community to avoid confusion.
- Establish trusted messaging and communication pathways - consider what to communicate and when: It is important to issue warnings as early as possible, but also not to issue too many warnings, otherwise they can create too much fear, or lose their importance.
- Translate the warnings to ensure clear understanding of the level of the warning and the likely impact
- Think about language and what words to use and how to communicate in different languages
- Think about how to automate data analysis and messaging for CBFEWS in the future

WhatsApp groups for communication[35]:

- Consider whether WhatsApp groups are appropriate, for example depending on data and signal availability.
- Consider what groups are relevant and who will play what role in these WhatsApp groups. If there is more than one group, it is also important to ensure consistent messaging across the groups.
- Think about data and making vulnerable settlements data free zones during periods of potential risk and flooding through data service providers.

[32] Tooley (2025)
[33] Focus group held with residents from Quarry Road West informal settlement focused on early warning and emergency toolkits, held at UKZN, 10/04/2025
[34] Technical CBFEWS meeting notes, 23/04/2025
[35] Technical CBFEWS meeting notes, 23/04/2025

Build Capacity

- Build capacity to understand the level of risk that is being communicated and the potential impact, so that responses can be tailored accordingly. Community-initiated responses are critical, rather than simply waiting for government to intervene[36].

Ensure redundancy across all elements of the system: Redundancy is important in a number of respects:

- **Scientific and technical systems:** Multiple systems need to generate data in case there are issues such as loadshedding, which can affect servers. Wherever possible, data and systems should be cloud-based so that network challenges do not compromise the system[37].
- **Sufficient elements up and running:** Work out how many elements of the system need to be functioning to be able to make reliable decisions and learn to be adaptive when one part of the system is not working.
- **Communication:** Ensure back-up communication systems are in place (e.g. if power goes down or if there is no signal).
- **Roles and responsibilities:** There is a need to build redundancy in terms of the roles and responsibilities of critical individuals performing roles in the CBFEWS at the community, scientific and technical knowledge and intermediary/interface levels[38].

Establish guidelines on flood responses:

Guidelines and/or response plans should be in place well ahead of flood events explaining what to do and how to help (across different actors, including residents) for different levels of warning[39].

Establish protocols for the CBFEWS:

It is critical to document processes, roles and responsibilities within the CBFEWS.

Operate across hybrid governance systems and spaces:

There is a need to balance the formal requirements of municipal systems (e.g. relating to sharing information, communication protocols) with informal systems that need to move more quickly and rely on more flexible and dynamic networks and systems.

Risk mapping in Pholani informal settlement.

[36] Tooley (2025)
[37] Tooley (2025))
[38] Focus group held with residents from Quarry Road West informal settlement focused on early warning and emergency toolkits, held at UKZN, 10/04/2025; Technical CBFEWS meeting notes, 23/04/2025
[39] Technical CBFEWS meeting notes, UKZN, 23/04/2025

The INACCT Resilience project has adopted a people-centered approach that can and should be upscaled to other projects.

Blueprint for Replication

Durban's CBFEWS offers a transferable model that can guide other African cities and towns. Key ingredients for replication include:

- **Trust and partnerships:** Sustained collaboration between communities, researchers, and local authorities.
- **Minimum data requirements:** At least one reliable upstream rainfall or stream gauge per catchment, and communication channels (e.g. WhatsApp, SMS).
- **Intermediaries:** Local universities or NGOs to bridge scientific and community knowledge.
- **Flexible governance:** Mechanisms that allow integration with national meteorological warnings while maintaining local autonomy.
- **Sustainable financing:** Integration into municipal budgets or small grant facilities for DRR.

This people-centred approach demonstrates how early warning systems can be localised, trusted, and lifesaving even in resource-constrained contexts.

7. UPSCALING THE CBFEWS AND OPPORTUNITIES FOR FURTHER WORK

Upscaling the CBFEWS needs to be done in innovative and resource-efficient ways, given that complex hydrological models and detailed community-based information (e.g. risk mapping, flood observations etc) are not available in all contexts. The expansion of CBFEWS is dependent on the ability to broaden the available scientific information needed to inform early warnings and to develop the context-specific local knowledge that must be integrated with scientific information when establishing CBFEWS in additional settlements.

There is considerable value added by INACCT and the other projects being co-implemented (e.g. TRMP Palmiet, EPIC Durban for risk reduction and knowledge generation, respectively) to support upscaling and avoid duplication. The CLARE Research for Impact Implementation Fund will also support further testing of the upscaling of CBFEWS in three additional settlements, all in different contexts and facing different challenges. This research will lead to the development of recommendations for broader upscaling. In addition, the work done under INACCT to develop correlations between rain and stream gauge measurements, will help facilitate the development of hydraulic models even in areas where other sources of data are not available.

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8. REFERENCES

Engel, K. (2025) 'Another year, another deadly disaster', Daily Maverick, 20 June.

EThekwini Municipality (2024) Integrated Development Plan 2024/2025. eThekwini Municipality, Durban.
Institute of Natural Resources (INR) (2023) Integrating knowledge systems in flood-risk modelling for sustainable solid waste management and flood resilience in urban informal settlements in South Africa: Situational Analysis Report.Pietermaritzburg: Institute of Natural Resources.

Lunga, W., Nkosi, M., Chirima, G., Madzivhandila, T., Ratshiedana, P., Ramaphakela, T., Majikijela, Y. and Musarurwa, C. (2023) Developing an early warning system to strengthen disaster resilience: experiences from flood-prone areas of KwaZulu-Natal province.

Mazeka, B., Sutherland, C., Buthelezi, S. and Khumalo, D. (2019) 'Community-based mapping methodology for climate change adaptation: a case study of Quarry Road West informal settlement, Durban, South Africa', in Cobbinah, P.B. and Addaney, M. (eds.) The Geography of Climate Change Adaptation in Urban Africa. Cham: Palgrave Macmillan.

O'Donoghue, S., Sutherland, C. and Leck, H. (2025) The development of the Palmiet Catchment Rehabilitation Project's Community-Based Flood Early Warning System. Draft report produced for the University of KwaZulu-Natal as part of the INACCT Resilience Project.

Pinto, I., Zachariah, M., Wolski, P., Landman, S., Phakula, V., Maluleke, W., Bopape, M-J., Engelbrecht, C., Jack, C., McClure, A., Bonnet, R., Vautard, R., Philip, S., Kew, S., Heinrich, D., Vahlberg, M., Singh, R., Arrighi, J., Thalheimer, L., van Aalst, M., Li, S., Sun, J., Vecchi, G., Yang, W., Tradowski, J., Otto, F. and Dipura, R. (2022) Climate change exacerbated rainfall causing devastating flooding in Eastern Southern Africa. World Weather Attribution (WWA), pp. 31.

Sutherland, C. (2025) 'Urban reform coalitions for transformative sustainability: reflections and lessons from Durban, South Africa', Environment and Urbanization, 37(1), pp. 116–135.

Sutherland, C. (2024) The direct and indirect climate change impacts, loss and damages in selected at-risk communities in Durban as a result of the April 2022 floods. Centre for Environmental Rights, Cape Town. Research Square. Available at: https://doi.org/10.21203/rs.3.rs-3383604/v1

Sutherland, C., Mazeka, B., Buthelezi, S., Khumalo, D. and Martel, P. (2019) Making informal settlements 'visible' through datafication: a case study of Quarry Road West informal settlement, Durban, South Africa.

Tooley, G. (2025) A technical description of eThekwini Municipality's Forecast Early Warning System. Draft report produced for the University of KwaZulu-Natal as part of the INACCT Resilience Project.

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CLARE is a flagship research programme on climate adaptation and resilience, funded mostly (about 90%) by UK Aid through the Foreign Commonwealth and Development Office (FCDO), and co-funded by the International Development Research Centre (IDRC), Canada. CLARE is bridging critical gaps between science and action by championing Southern leadership to enable socially inclusive and sustainable action to build resilience to climate change and natural hazards.

ABOUT INACCT RESILIENCE

The Designing Inclusive African Coastal City Resilience (INACCT) is an action-oriented research project focused on two coastal cities: eThekwini (Durban) in South Africa, and Beira in Mozambique, both having recently experienced extreme climate-related flooding that caused severe urban and environmental damage, displacement and loss of life.

The project aims to strengthen proactive, inclusive and evidence-informed urban resilience planning, particularly for informal settlements and vulnerable communities in coastal cities in Africa. The research uses a transdisciplinary approach, emphasising co-learning and co-design of inclusive solutions, integrating multiple types of knowledge and evidence from a range of stakeholder perspectives.

INACCT Resilience is funded through the Climate Adaptation and Resilience (CLARE) initiative. CLARE is a £110m, UK-Canada framework research programme on Climate Adaptation and Resilience, aiming to enable socially inclusive and sustainable action to build resilience to climate change and natural hazards. CLARE is an initiative jointly designed, funded and run by the UK Foreign Commonwealth and Development Office and Canada's International Development Research Centre. CLARE is primarily funded by UK aid from the UK government, along with the International Development Research Centre, Canada.

Beira

In March 2019, tropical Cyclone Idai caused severe flooding that displaced 16,000 and killed over 600 people in Beira and left 80% of the city in ruins. Vulnerable communities were hardest hit by these events, which had social, economic and environmental implications, and caused major disruptions to their everyday lives. In Beira, rapid analyses described differentiated impacts of, and responses to Cyclone Idai, including: more pronounced/long lasting housing insecurity amongst female-headed households.

eThekwini

In April 2022, heavy rainfall led to flooding and landslides in eThekwini, which had devastating and extensive city wide consequences leading to loss of life and the displacement of over 40,000 people. Informal settlements, peri-urban areas and vulnerable communities were particularly hard hit, losing their houses, as well as their land. Despite eThekwini being a forerunner in integrated resilience action, infrastructure including roads, wastewater treatment works, and basic services were severely damaged by the floods, which has placed increased pressure on municipalities already struggling with service backlogs and the financing of services.

Community discussion in Tshelimnyama as part of efforts to pilot the upscaling of the CBFEWS.